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On Negative Photoconductivity and the Induced Electron Transitions

N. G. Bassov, O. N. Krokhin, L. M. Lisitzin, E. P. Markin, B. D. Ossipov

Recently a number of methods was suggested to obtain so called "negative temperature" states in semiconductors [1, 2, 3].

As shown in [3], at indirect transitions the concentration of carriers, at which the negative temperature in respect to band to band transitions can be obtained is comparatively not large. It is by several orders of magnitude lower than the concentration, at which a negative absorbtion for photons with energies comparable with forbidden gap width can take place.

For negative absorbtion of light can exist if the probability of induced photon emission in the band to band transition must be much larger than the probability of photon absorbtion in the reverse process, to compensate the absorbtion at intrinsic transitions. However, the processes connected with intra-band absorbtion, i.e., free carrier absorbtion practically don't alter the conductivity, as the total number of free carriers does not change. The band to band transitions induced by incident photons in a semiconductor having negative temperature state reduce the free carriers concentration and the conductivity.

Thus a semiconductor in the state of negative temperature in respect to band to band transitions has to have negative photoconductivity at the irradiation by photons with the energy near to forbidden gap width.

The measurements of spectral response of photoconductivity in a semiconductor permits to find a state of negative temperature even if there is no negative absorbtion.

The following experiments were made to obtain and detect negative temperature state in silicon: A sample having a temperature near to 4°K was irradiated by light with wavelength less than 0.7 μ, which resulted in appreciable increase of conductivity.

At the additional irradiation by weak monochromatic light, for many samples, in a narrow spectral region near 1.1 μ a decrease of conductivity, i.e., negative photoconductivity was observed. One can think that the conductivity decrease detected is a result of negative temperature state; however, other explanations of the effect, for instance by impurity photoconductivity, cannot be excluded.

P. N. Lebedev Institute of Physics
Academy of Sciences, USSR

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(2) N. G. Bassov, O. N. Krokhin, Yu. M. Popov, IETP 39, 1001, (1960).

(3) N. G. Bassov, O. N. Krokhin, Yu. M. Popov, IETP, 40, 1203 (1961).

On Field Emission from Metals into Alkaline Halide Crystals

E. A. Konorova, L. A. Sorokina

P. N. Lebedev Institute of Physics
Levinsky Prospect 53
Moscow USSR

The results of the experimental investigation of conductivity of alkaline halide crystals in high electric fields conducted by us in earlier work (Izv Acad. Sci. USSR No. 1, 1961) made us to suggest that in the fields about 3 - 5 x 10^5 V/cm, auto-electron emission begins from cathode metal into the crystal.

To confirm this suggestion we measured impurity photoconductivity in uncolored alkaline halide crystals, stimulated by high electric field. It was shown that from certain threshold field value, such photoconductivity takes place in uncolored KBr, KCl and NaCl crystals.

The main results of the work are:

(1) On the application of a sufficient field (2 - 6 x 10^5 V/cm) electron space charge is formed; the charge is fixed at capture levels. The magnitude of the space charge corresponds to the average electron density of 10^{12} - 10^{14} - cm^{-3} and is proportional to the field strength.

(2) The wavelength of light exciting the photoconductivity corresponds to the F-band absorbtion. We did not find other extrinsic photoconductivity maxima.

(3) The dependence of photo-current on the voltage applied follows approximately an exponential law:

$$I = A e^{\alpha U}$$

where U is the voltage applied, α and A are constant coefficients.

This dependence cannot be described by second power law, that could be expected as a result of two factors depending on field strength: linearly, the density of electrons fixed at capture centers, and by the drift distance of photoelectrons. It is thought that the value of photocurrent is affected by the

distribution of space charge in the crystal.

(4) Both the magnitude of space charge and photocurrent do not depend on the sample temperature, between room temperature and -180°C.

The experimental data show that the occupation of F-center level in the crystal is connected with electric field. As the excitation from valence band and the levels near to it is hardly probable, one has to assume that the cathode is the source of electrons.

The work function from gold into alkaline-halide crystal obtained in our experiments is small (about 0.5 ev). The surface treatment before electrode evaporation (cleavage surface included) did not affect the currents substantially. Thus, one has to think that the low work function is not a result of the distortion of the field by the electrode geometry.

The second reason distorting the field near cathode may be the formation of positive space charge.

We measured dark currents in KCl and KBr single crystals using rectangular high field pulses lasting 50 to 1000 μsec. It was found that emission current pulses (here currents are large, up to 10^{-3} - 10^{-4} A) do not follow the voltage pulses and have some inertia.

The measurements show that space charges increase the field near cathode to some extent, but this increase is not large enough to explain field emission from a surface with work function of 3 - 3.5 ev (a calculated value for gold and alkaline-halide crystal).

Thus, one has to suggest that the work function is low. It seems possible that it is a result of the precipitation of alkaline metal atoms from crystal on electrode, as monoatomic layers of these metals decrease the work function.